Electric Charge Meter

In search of the Coulomb

Design by B. Kainka

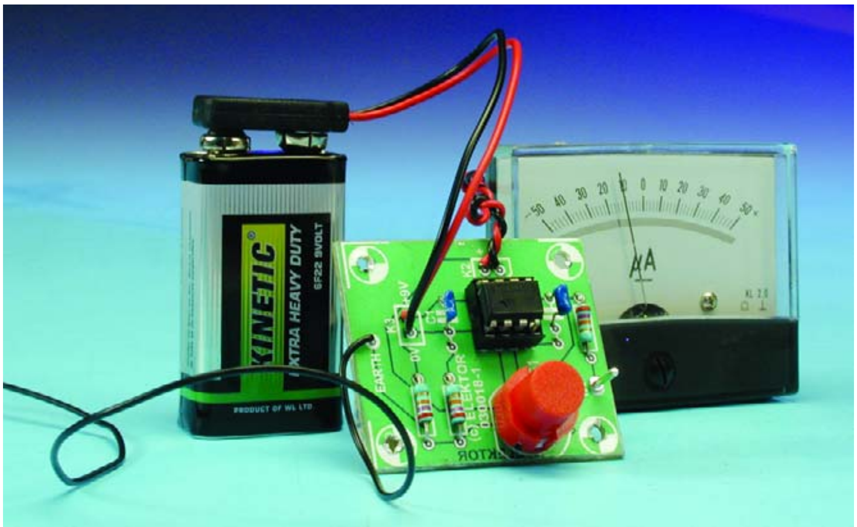
Just knowing that electrostatic charges can damage and destroy expensive components is fine, but being able to measure them is even better because it allows you to put a finger on potential problems (pun intended).

Static charges are feared in all electronics laboratories and workshops — and rightly so because a vinyl carpet has the ability to charge up persons to voltages in excess of 20 kV. Careless touching of sensitive ICs can cause their instant demise. However, problematic as they are, static charges also have very interesting aspects. For example, it has been observed that two persons walking the same carpet with different shoes can accumulate opposite static charges, that is, release voltages with different polarities (positive and negative). Many more questions remain to be answered by physics. For example, it is true that women generally accumulate a negative static charge whereas men carry a positive one, or is this just a rumour spread by ‘bachelors for life’? Obviously, the question may only be answered by statistically founded research to which *Elektor* readers are kindly invited to contribute.

In experiments with electrostatic charges, the decisive quantity is not voltage but electric charge, expressed in coulombs. A high voltage is not necessarily dangerous when present on a relatively small object. The decisive relation is expressed by the equation

charge = capacitance × voltage

A human body represents a capacitance of just a few picofarads. When charged to a couple of kilovolts (as may happen in everyday situations) the corresponding charge is of the order of a few hundred nanocoulombs (nC).



Circuit operation

Basically, the electric charge meter consists of a measurement capacitor coupled to a high-impedance measurement amplifier. A charged body should briefly touch the measurement input. From elementary physics, you should remember that this causes the charge to be distributed equally between charged body and capacitor, so the latter is charged to an extent that an be measured with the aid of a charge meter and a regular voltmeter. In practice, assuming that a measurement capacitor of 100 nF is used, a voltage increase of 1 V corresponds to a measured charge of 100 nC. The circuit supply voltage of 9 V affords a measurement range of about –300 nC to +300 nC.

Because an extremely high impedance input is required (in order to prevent charge loss) an opamp with a FET (field effect transistor) input is applied in our circuit. Such is the input impedance of the opamp used here that the measured voltage shows very little or no decrease even after several minutes. The measurement amplifier proper

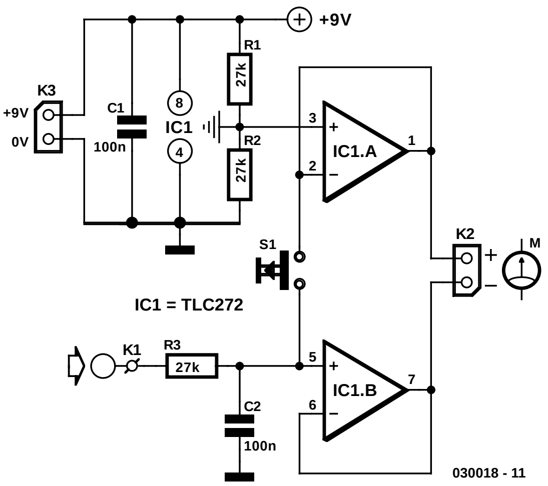


Figure 1. The circuit of the Electric Charge Meter is simplicity itself.

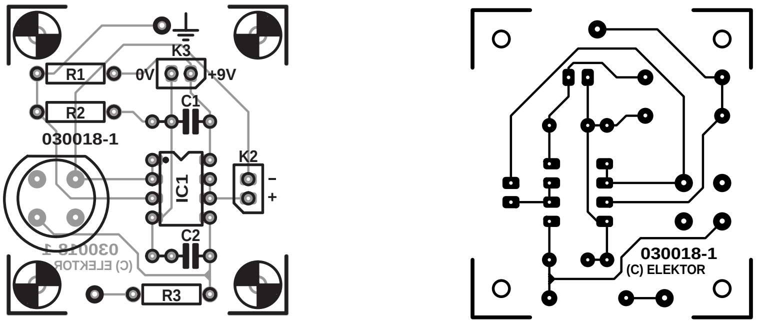


Figure 2. PCB layout with component mounting plan.

is configured as a unity-gain (×1) buffer with full feedback. The second opamp, IC1, supplies a low-impedance bias voltage of half the supply rail. This arrangement allows a simple voltage source to be used to measure both polarities, provided the bias voltage is fully earthed, for example, by a connection to a copper water pipe.

Before the actual measurement can begin, you have to press the Zero pushbutton. Contrary to what you might expect, this causes the measurement capacitor to be charged to half the supply voltage rather than being discharged to 0 V. However, because the instrument's negative terminal is connected to the 4.5-V (mid-supply) level, it will duly indicate 'zero' charge.

Practical use

Next we can bring a charged body into contact with the measurement input. Depending on its charge polarity, the body can add to the charge already present on the capacitor, or discharge it to some extent. The resulting voltage increase or decrease that can be observed on the meter indicates the charge level as well its polarity. The duration of the contact is immaterial in this respect — what's imperative is to keep the body itself properly isolated when the measurement takes place.

From your physics classes you may (fondly) remember that experiments with electrostatic voltages and discharges are subject to haphazard results. As a matter of course, the actual amount of charge carried on a body is heavily dependent on all sorts of leakage, isolation defects, not forgetting the relatively humidity of the (classroom) air. In general, electrostatic discharges are easier to observe under relatively dry air conditions, to which we should add that free ions are capable of reversing the charge polarity of free air. This ability can be proved by using the Electric Charge Meter to verify the operation of air ionizers.

(030018-1)

COMPONENTS LIST

Resistors:
R1,R2,R3 = 27kΩ

Capacitors:
C1,C2 = 100nF

Semiconductors:
IC1 = TLC272

Miscellaneous:
K1 = PCB solder pin
K2 = connection for moving-coil or multimeter
K3 = connection for 9-V battery (with clip-on connector)
S1 = pushbutton, 1 make contact
PCB, order code 030018-1 (available from The PCBShop)